Beyond emissions and economics: rethinking the co-benefits of Nordic Electric Vehicles (EVs) and Vehicle-To-Grid (V2G)

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Abstract: Electric vehicles and vehicle-to-grid are one option to achieve the transition to decarbonizing society. Despite perceived advantages of cost-savings and carbon reductions, such technologies have faced various barriers that has prevented wide-scale adoption. While much literature has carefully investigated the techno-economics dimensions to electric mobility, we ask: what are the full set of benefits that EVs and V2G offer? To provide an answer, the authors conducted 227 semi-structured interviews with transportation and electricity experts from over 200 institutions across the Nordic region. Results show that there is an extensive range of benefits for both EVs and V2G, with experts suggesting 29 and 25 categories of benefits for EVs and V2G, respectively. Though the experts covered the obvious benefits of economic savings, emissions, and renewable energy integration, several other novel benefits were identified. The second and third most common discussed EV benefit was noise reduction and better performance, which are typically not widely discussed. Similarly we find that V2G benefits covered topics like vehicle-to-home and solar integration, as well as more novel benefits, like vehicle-to-telescope and emergency power backup. The article concludes with a discussion of future research and benefits in the context of energy research and analysis.

Keywords: electric vehicles, vehicle-to-grid, climate change, transport policy

1. Introduction

Electric vehicles (EVs) and vehicle-to-grid (V2G) are often regarded as a key aspect of the sociotechnical transition to decarbonize transportation. In order to optimize this transition, it is essential for policymakers to understand the entirety of the benefits EVs and V2G may offer, as well as the challenges they would pose. A variety of previous papers have explored the potential benefits of EVs and V2G could bring to society, such as climate change mitigation, local health emissions, and lower cost of ownership, though they often only discuss these benefits in the context of the barriers EVs and V2G also face (Sovacool and Hirsh 2009; Egbue and Long 2012; Sovacool, Axsen, and Kempton 2017). Other papers have focused on characterizing a single benefit, such as the quantification of emissions benefits EVs and V2G offer (Buekers et al. 2014; Archsmith, Kendall, and Rapson 2015; Sioshansi and Denholm 2009) or reducing the heat island effect (Li et al. 2015). No previous work has sought solely to comprehensively describe the full range of co-benefits of EVs and V2G.

For example, papers that compare the costs and benefits of EVs and V2G focus exclusively on how emissions and economics impact the cost-effectiveness of EVs in context of alternative transport options (Carlsson and Johansson-Stenman 2003; Lemoine, Kammen, and Farrell 2008; Villar et al. 2013; Noel and McCormack 2014). While some may recognize there are other benefits EVs could offer, such as noise, they are not included in their analysis, due to some benefits being admittedly difficult to monetize and include in comparisons (Carlsson and Johansson-Stenman 2003). Similarly, the benefits of V2G tend to focus on the economic and emissions benefits of services provided to the grid (Sovacool and Hirsh 2009; Lopes et al. 2009; Noel and McCormack 2014). Likewise, EVs and V2G are often included in analyses of large-scale renewable integration, but are also only evaluated on their economic and emission costs and benefits (Jacobson and Delucchi 2011; Budischak et al. 2013; Noel et al. 2017). Nonetheless, there may be more benefits to EVs and V2G beyond these two, and if not included, these papers may unintentionally suggest suboptimal transport and decarbonization policy. We endeavor to describe the full context of benefits of EVs and V2G beyond costs and carbon.

This paper aims to explore the benefits of EVs and V2G past the current narrow techno-economic focus in the literature by characterizing the entirety of the benefits these technologies could offer. To describe the benefits, the authors conducted 227 semi-structured interviews with 257 participants from over 200 institutions across the five Nordic countries. Given the electrical nature of EVs and V2G, those interviewed were selected to represent the diverse array of stakeholders involved with the transportation and power systems, technology, policy and practice. Selected experts were from national government ministries, agencies, and departments; local government ministries, agencies, and departments; regulatory authorities and bodies; universities and research institutes; power transmission, distribution and supply utilities; automobile manufacturers and car dealerships; private sector companies; and industry groups and civil society organizations.

We find that the experts presented a diversity of benefits for both EVs and V2G, advancing different benefits of each, 29 and 25 respectively. We find that the experts discussed the obvious benefits of emissions and economics for both EVs and V2G, as well as several novel benefits not included in the aforementioned EV cost-benefit analyses. The benefits tended to focus more on an individual level, as opposed to societal benefits, such as noise and advantageous performance for EVs, and V2G integration to homes with solar panel.

We present the full results below, and then conclude with a discussion of the implications for future EV research and transport policy.

2. Materials & Methods

To explore the benefits surrounding electric mobility, namely electric vehicles and vehicle-to-grid technology, the authors relied primarily on original data collected through semi-structured research interviews. This methodology was applied on a regional context taking the five Nordic countries as place of study, since it is recognized that these countries have traditionally had aggressive push of climate, energy and transport policy agendas emerging as leading nations in electric vehicle uptake (Norway), or pioneers of wind energy (Denmark), or geothermal energy (Iceland)(IEA 2016).

The implementation of *semi-structured interviews* allows the authors to have guidance and flexibility, by asking a set of fixed questions to then, create a conversational channel of information-gathering, allowing space for spontaneous responses that add depth and in some instances unforeseen narratives to the research (Harrell and Bradley 2009). These semi-structured form of interviewing is suitable when the objective of the research is to understand complex elements and their intersection with perceptions, beliefs, and values (Yin 2003). Lastly, the authors selected this research method as it allowed for novel and up-to-date data (at the time of the interview) which was not available in other formats, since official documents can take months or even years to be published.

The authors conducted 227 semi-structured interviews with 257 participants from over 200 institutions across the five countries of Denmark, Finland, Iceland, Norway and Sweden from September 2016 to May 2017 (See appendix 1 for an overview). Those interviewed were selected to represent the diverse array of stakeholders involved with transport technology, policy and practice, and included members of:

- National government ministries, agencies, and departments including the Ministry of Industries & Innovation (Iceland), Ministry of Environment and Energy (Sweden), Ministry of Finance (Finland), and Ministry of Taxation (Denmark):
- Local government ministries, agencies, and departments including the Akureyri Municipality (Iceland), City of Stockholm (Sweden), Aarhus Kommune (Denmark), City of Tampere (Finland), City of Oslo (Norway), and Trondheim Kommune (Norway);
- Regulatory authorities and bodies including the National Energy Authority (Iceland), Danish Transport Authority, Icelandic Transport Authority, Helsinki Regional Transport Authority (Finland) and Trafi (Finland);
- Universities and research institutes including the University of Iceland, Swedish Environmental Institute, DTU (Denmark), Aalborg University (Denmark), VTT Technical Research Centre (Finland), NTNU (Norway), and the Arctic University of Norway;
- Electricty industry players such as ON Energy (Iceland), E.ON (Sweden), Vattenfall (Sweden), Energinet (Denmark), DONG (Denmark), Fingrid (Finland), Elenia (Finland) and Statnett (Norway);
- Automobile manufacturers and dealerships including the BMW Group (Norway), Volvo (Sweden), Nissan Nordic (Finland), Volkswagen (Norway), and Renault (Denmark);

- Private sector companies including Siemens Mobility (Denmark), Nuvve (Denmark), Fortrum (Finland), Virta (Finland), Clever (Sweden), Nordpool, (Sweden), Norske Hydrogen (Norway), Microsoft (Norway) and Schneider Electric (Norway);
- Industry groups and civil society organizations such as Danske Elbil Alliance (Denmark), Finnish Petroleum and Biofuels Association, Tesla Club (Finland), Power Circle (Sweden) and the Norwegian Electric Vehicle Association.

As such, we targeted respondents with different backgrounds and from dissimilar sectors – but all in some way related to electric mobility and/or vehicle-to-grid - to capture a diversity of perspectives within the sample. Such techniques have been shown to increase the validity of research in the fields of critical stakeholder analysis, political science, statistics, energy studies, and public health. Participation was voluntary with no compensation.

Interviews lasted generally between thirty and ninety minutes in their duration, and participants were asked one main question: “What are the full set of benefits that electric vehicles and vehicle-to-grid offer?” and the following context in the interview was developed according to the background of each respondent. Other questions, such as the barriers that EVs and V2G face, were also asked, but these results are reported in separate papers. In the study, participants were not prompted for responses, talked on a personal level, and were permitted to answer as long or as detailed as they wished. This approach is sometimes termed *ethnographic* as it involves taking what the participants and experts said at face value, we did not correct them, critique them, suggest answers, or view our own values and attitudes as superior. This technique requires researchers to acknowledge that their position is just as valid of those they are interviewing, and implies a special responsibility to look at local events and cases within their own frames of reference (Atkinson 1988; Martello and Jasanoff 2004). Each interview was recorded and then fully transcribed and analyzed. Each participant was also given a unique respondent number (which we refer to whenever presenting interview data).

3. Results and Discussion

3.1. EV Benefits

In total, our data collection and analysis resulted in 29 different categories of the benefits that the experts identified, with Figure 1a summarizing the frequency of each benefit and Figure 1b offering a top 10 overview per focus area indicating slightly different argumentation patterns for experts coming from different directions to EVs but overall similar priorities Here we discuss the five most commonly discussed EV benefits (emissions, noise, performance, economic savings, and renewable energy integration), and then summarize the remaining benefits.

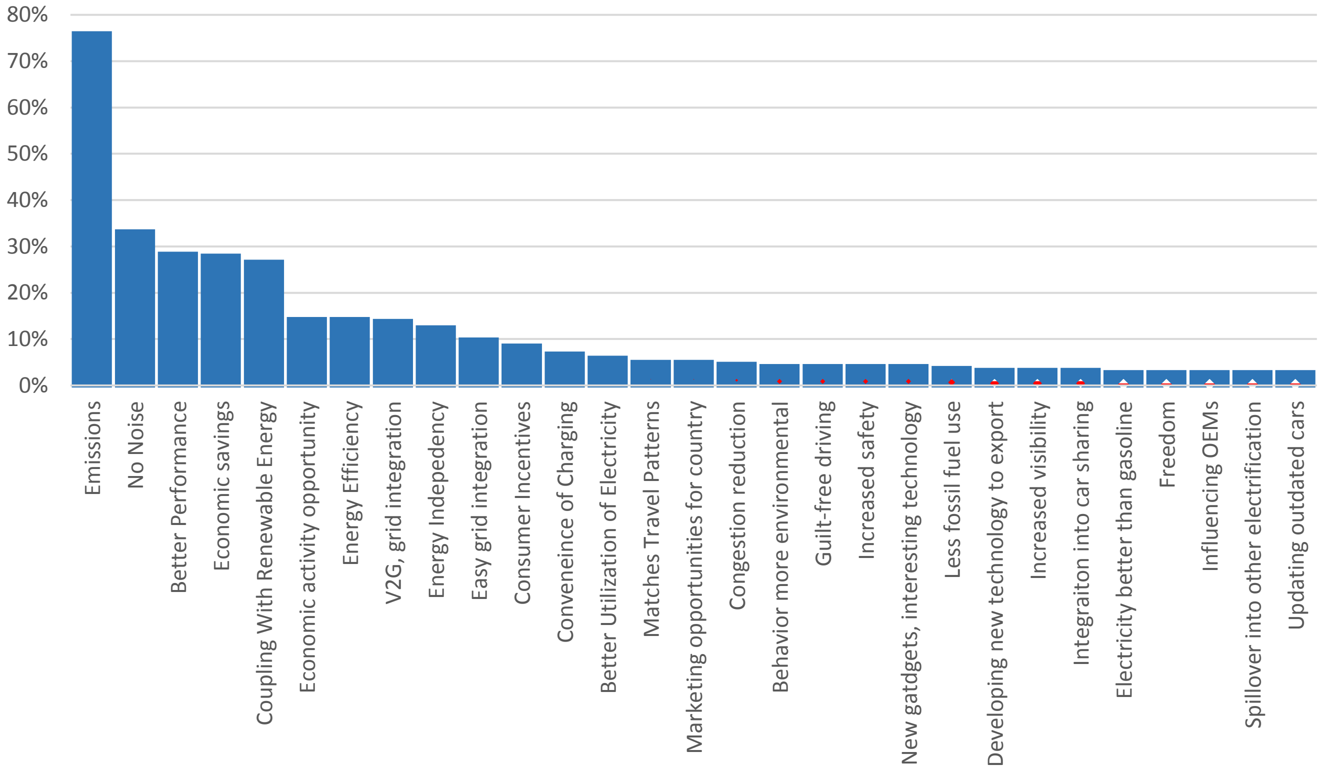
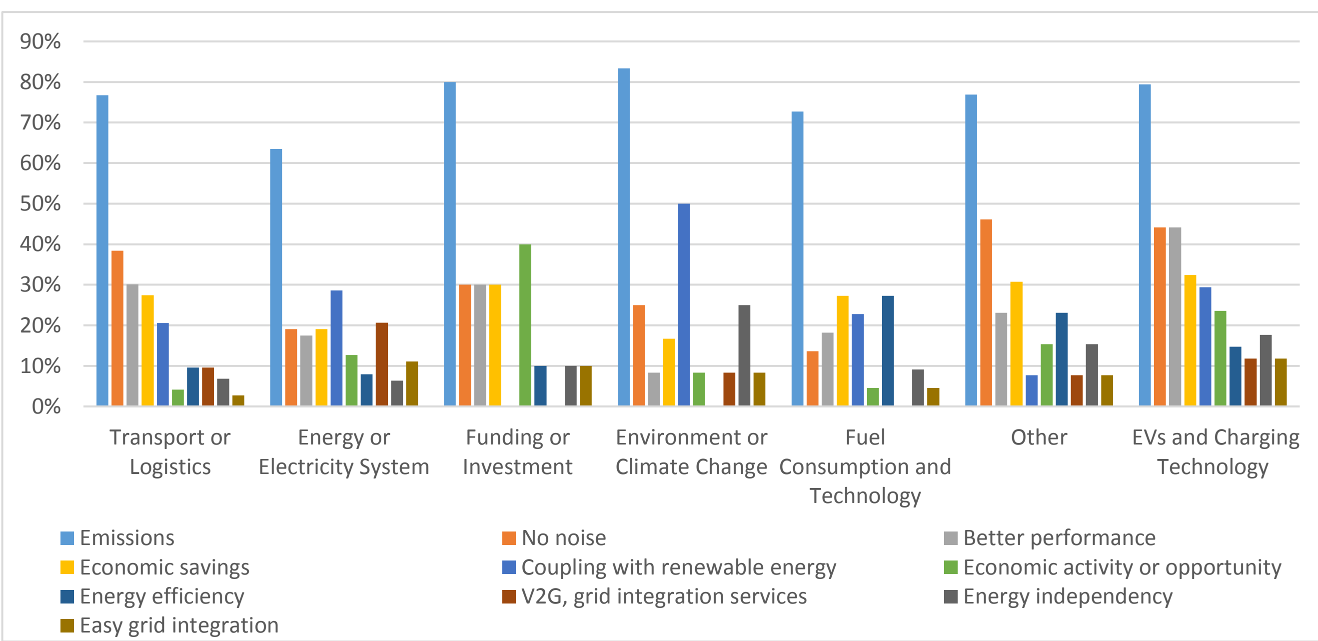


Figure 1a. Co-Benefits of Electric Vehicles Identified by Interview

Figure 1b. Top 10 Co-benefits of EVs per focus area of interview



While there was a great variety of the types of benefits discussed, by far the most dominant benefit of electric vehicles was the impact they would have on reducing emissions. Of the 227 interviews, 167 characterized the benefits of EVs in terms of their environmental benefits, representing over 73% of the interviews. Of those who mentioned emissions, 99 interviews explicitly tie this benefit to the carbon emission reductions of EVs as compared to ICEVs, and while 94 interviews also explicitly mention the impacts EVs would have on decreasing local health emissions, such as NO_X and particle matter. On their own, carbon and local emissions would each be more discussed by the experts than the second most commonly discussed topic, showing that emissions dominated the discussion of EV benefits. In fact, the carbon benefits of EVs had become almost too obvious –as R232 put it:

> "*Well again the whole picture is the decarbonization…We didn't mention it because it's so obvious*."

Indeed, though emissions are already the most commonly discussed, it perhaps could have even been *more* discussed had experts not simply assumed these benefits were too obvious to warrant further discussion. In many cases, it seemed like the experts were merely checking off the box of emissions before moving onto more novel benefits of EVs.

Surprisingly, the second most common benefit discussed by the experts was the noise reduction that electrification can offer. The lack of noise was characterized for the individual user (e.g. the driver will enjoy the quietness and the simplicity of an EV), the non-users (i.e. cyclists or pedestrians), as well as from an urban planning perspective. Many viewed noise emissions from ICE vehicles as a great cost, as it reduces living conditions for those living near major roads within the city, and thus EVs could increase both housing prices and improve local health. As an example, in Denmark R120 told us that noise is considered the new pollutant that EVs could help solve:

> *"We see noise as being the new pollutant, which is not really tracked but definitely has a big effect, we see five hundred, six hundred people die prematurely as a direct cause of too high of sound level all over the day and night in Copenhagen."*

This was not an issue specific to Denmark, but was present across the Nordic region, as R208 added that Oslo city center also faces similar challenges that electrification could likewise solve:

> *"But also it has a significant contribution to noise, and noise levels inner city is actually a large health problem. So that's part of that environmental sort of, or problems that will be solved as well."*

The reduction in noise levels was tied not only to personal vehicles, but also commonly to electric buses and other heavier duty vehicles. Heavy duty forms of transportation, namely city buses and lorries, posed a challenge for city planners with road noise impacting time nearby houses. As R73 describes, the future of urban planning could be quite different given the removal of noise from transportation:

> "*I think there a lot of things like pollution, being quiet. You can also drive inside the buildings. There are a lot of new possibilities with the EV's*."

The possibility of driving vehicles inside buildings may sound a bit farfetched, but many experts recognized the substantial benefits electrification would have on the optimization of traffic planning, and its subsequent impacts on housing prices, city planning, and individual's health. For example, R248 discussed how bus drivers were healthier after switching to an electric bus:

> *"After 10 hours of driving an electric bus, they are about as tired as if they have been driving a diesel bus for 7 hours. So they came home after the day, and they were able to do many things which they had not, were able to sleep more than before, do training or proactive [exercising]"*

Next, the third most discussed benefit was the better performance of EVs as compared to internal combustion engine vehicles (ICEVs). These discussions often included the relative better acceleration and energy efficiency of EVs due to their instant torque, the more comfortable driving (e.g. less vibration and noise), and overall better handling and weight distribution. Indeed, many experts actually viewed the better performance of EVs as a central impetus to implement EVs. For example, when discussing reasons for government to develop EV policy, R196 told us:

> *"[W]hy would you do electric car? Well, because it's a superior technology then. If for no other reason, do it for that."*

It may seem counter-intuitive for the government to incentivize a technology if only to increase the welfare of private drivers, but, for R196, the better performance of EVs warranted government support. But pushing aside the question of the role of government, the benefits of EVs go far beyond simply costs and carbon.

Moving along to the fourth most common benefit, the economic savings of EVs was not as widely discussed as the authors expected, given its prevalence in the literature (Carlsson and Johansson-Stenman 2003; Wu, Inderbitzin, and Bening 2015), as only a quarter of experts discussed economic savings in any manner. Looking deeper into those who did discuss it, an overwhelming amount of experts explicitly characterized the economic benefits from an individual point of view, as opposed to the potential societal economic savings (36 to only 14, respectively). Those who did recognize the societal level of savings foresaw substantial changes to overall living cost, as R119 noted:

> *"So looking at the whole cost of transportation and mobility of the population in Denmark and Aarhus, it's going to be much cheaper in an electrical car, so it's going to lower the living cost and the production cost of the whole society to go to electrical cars."*

However, more often than not, the experts tended to focus on individual economics. While the authors recognize that individual savings is an important argument for the deployment of EVs, the lack of widespread discussion of societal savings – which some scholars calculate at billions (Noel et al. 2017) – may imply that experts could be generally incognizant of one of the largest benefits EVs can offer society. As these savings could then provide economic activity for consumers now freed from spending money on petrol.

Fifth, many experts discussed the benefit of electric vehicles in the connection to renewable electricity. Generally, the experts discussed the integration of EVs and renewable electricity in terms of renewable electricity that already existed, e.g. higher utilization rates of wind currently in the system. However, a small subset of experts (9 out of the total of 55 interviews discussed renewable energy) discussed the possibility of using EVs as a means to integrate *new* renewable electricity. Combining this with the set of experts that, unprompted, saw V2G as a central benefit EVs could provide in the future, more than a third saw the central benefits of EVs to include grid services and renewable energy integration.

Importantly, there was a wide variety of benefits beyond these five central benefits. Beyond these central topics, the remaining benefits were diverse, including energy efficiency and independency. Interestingly, despite the relatively slow uptake of EVs outside of Norway, several experts espoused the benefit that EVs are easy to integrate – either into the electricity system (17 interviews), or into the daily travel patterns of society (6). Perhaps mirroring developments in the solar industry (The Solar Foundation 2017), in 12% of the interviews experts expected EVs to bring new job opportunities and increase local economic activity. Notably, an interesting benefit of EVs discussed in 4% of the interviews was the convenience of charging at more convenient locations, namely at one's home or one's work, thereby reducing the necessity to go the gas station. In fact, experts such as R245 believed that this was a benefit that needed to be better communicated to the public:

> *"And then I think people that get really used to the electric vehicle, they like the convenience, because typically they only charge the vehicle at home or at their place of work. That is also very convenient. And I think that is something that is under communicated to potential EV buyers. Because that is really convenient, if you don't ever have to stop by a refueling station and make a detour for that."*

Of the remaining benefits (of which fewer than 2% of the experts brought up), the responses were increasingly creative. For example, these benefits included the idea that EVs would lead to both safer cars as well as less congestion with the advent of automation technology, where automated and autonomous vehicles will be inherently powered by electricity. Additionally, some presented the idea that EVs would lead people to change their behavior in other ways to become more environmental. For example, while we were discussing their own behavior changing after driving an EV, R85 articulates:

> *"[I]t does change people, a lot of people say that. So there is a lot of, that's a very interesting psychological thing that is going on, just because you have a different car."*

Thus, implementation of EVs may increase individual's knowledge of energy use and environmental impacts of transport demand. Others also believed that EVs would change people's behavior to increase their willingness to consider new modes of transportation, such as car sharing and automated vehicles.

Overall these results, see Figure 1, show that there is to some extent a heterogeneous narrative in the main perceived advantages of EV technology. While the positive environmental attributes of carbon and local emissions dominated discussions, EVs embody other benefits that are not to-date well documented in the literature or other outlets. The advantages of noise reduction, the social economic benefits, convenience of charging, or better performance are beginning to be apparent to experts on the field.

3.2. V2G Benefits

The benefits of V2G are much more pluralistic compared to the experts' view of EV benefits. Overall knowledge of V2G was less defined; only 149 interviews, representing just under 66% of the sample, brought up some benefits of V2G, with many being unfamiliar with the topic (compared to over 95% of the interviews expressing a benefit of EVs). We categorized those who did discuss a benefit of V2G into 25 categories, summarized in Figure 2a, while figure 2b confirms the slightly higher response rates of experts from the EV and charging industry and experts from the grid side.

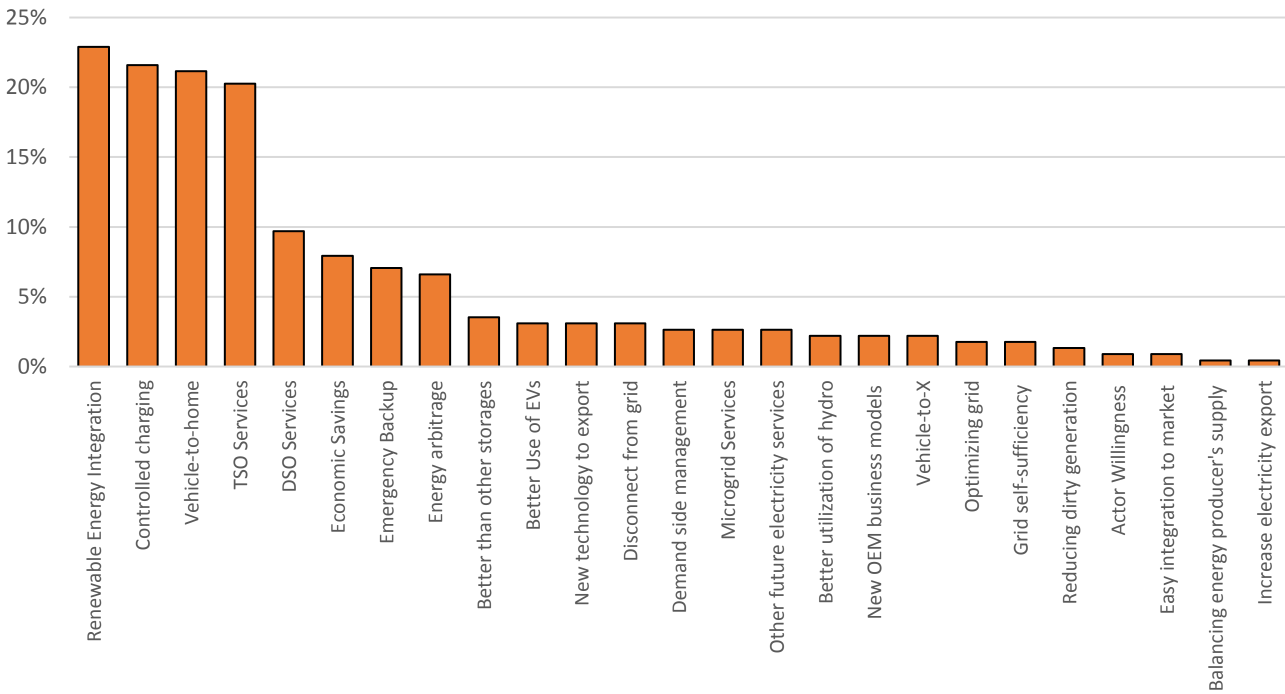
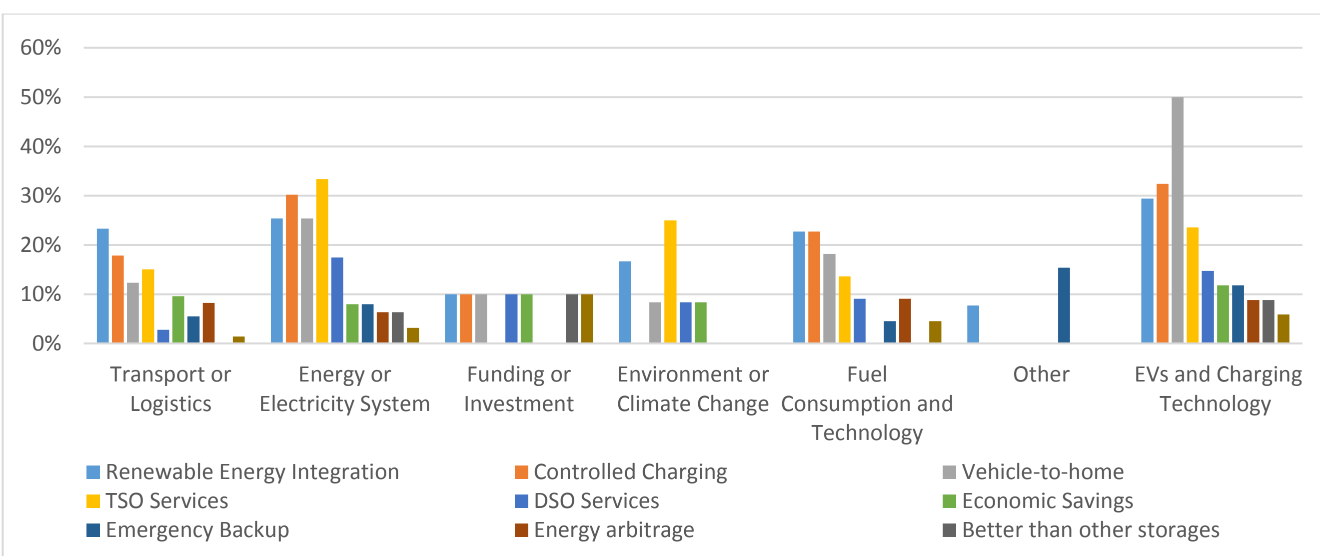


Figure 2a: Co-Benefits of Vehicle-to-Grid Identified by Interviews

Figure 2b: Top 10 Co-benefits of V2G per focus area



First and foremost, the most discussed benefit of V2G was its capacity to integrate new intermittent sources of renewable energy, brought up by 52 experts. Surprisingly, V2G was twice as likely to be discussed explicitly in terms of solar energy (33 experts) compared to wind energy (only 15). For most experts, the benefits of V2G were less focused on utility scale wind (despite the Nordic region's wind resources), but rather, the benefits focused on more local solar production. Indeed, though the connection of V2G and utility-scale renewable energy integration is well established in the literature (Lund and Kempton 2008; Noel et al. 2017), the experts connected the idea of renewable integration more closely to vehicle-to-home (V2H), another widely discussed benefit of V2G. For example, R70 overtly preferred connecting solar and V2H:

"*If you think you're getting solar and wind but especially solar to store, you could connect EV to a house and even out the highs and lows in your house. That's something that would make more sense in a way."*

For many experts, solar PV and V2H was a natural connection and perhaps more intuitive than the complex services V2G could provide, such as frequency regulation. Surprisingly, V2H was slightly more common than the variety grid services that V2G could provide (see below). The gravitation of experts towards V2H is quite peculiar given that a recent systematic review of the V2G literature indicated that the literature focused substantially more on grid-level services rather than V2H (Sovacool et al., 2018). This perhaps reflects a disconnect between academia and industry, where V2G remains quite a novel concept and only until recently more publicly available pilot projects are being developed outside of the U.S. and Denmark.

The next most discussed benefit of V2G was simply controlled charging, also known as smart charging or V1G. The context of controlled charging varied widely among the experts, with some seeing it as a stepping stone and for others, the upper bound. First, controlled charging seemed to be a very intuitive benefit of V2G for many of the experts who were unsure of the future viability of V2G. For example, R61 saw controlled charging as the first and most certain benefit of V2G:

> *"[T]he first step is probably just, not storage, but it's basically that you can decide when, that utilities should be able to decide when you are recharge your vehicle."*

However, others were more uncertain about the prospects of V2G beyond controlled charging, as R158 expressed their concern of the additional complexity of V2G compared to controlled charging:

> *Smart charging the first place, because that must be created and that's the easy one that the cars are charged…but of course vehicle to grid is much more complicated.*

On the other hand, other experts were more certain of the future of V2G, but still clarified that controlled charging would be the first step of a clear path that would explicitly expand to bidirectionality. R137 saw controlled charging as the stepping stone to V2G:

> *"Yea, first layer for the benefits comes from small-scale demand response services, mainly to reduce the charging power, in a cluster of chargers, locally or in a wider clusters. And, the second phase of that is of course vehicle-to-grid, so moving the electricity both ways."*

Nonetheless, controlled charging was conversely characterized as the ceiling of V2G, as many experts saw it as the only valuable service EVs would provide, and were skeptical that bidirectionality would add any value. As R130 showed, only flexibility on charging the EV was valuable:

"I could easily see some flexible measure to the battery. I cannot see the opposite way around that the battery delivers electricity to the grid, that would not be easy for me to understand."

Likewise, R125, who was wary that bidirectionality could provide any significant levels of value, reiterated that controlled charging was an obvious benefit:

"And of course, I can see smart charging electric vehicles of course is a major obvious thing to do."

Controlled charging was portrayed in a variety of contexts, often conflicting. However, as indicated above, the majority of these experts did not connect it to the wider set of services and benefits V2G could provide (Knezovic et al. 2015; Kempton and Tomić 2005), for example, finding that V2G could provide net revenues of around $2,500 per year for participation in ancillary service market participation. Over the lifetime of a typical vehicle, these revenues add up to around $20,000 to $45,000 in the U.S., depending on the electricity grid (Noori et al. 2016). While this may be indicative of V2G's relative immaturity, it may also show the lack of cognizance, even among transport and electricity experts, of the wider variety of benefits that V2G could provide (as compared to the many creative benefits experts discussed for EVs), and is actually currently providing within the Nordics, in Denmark (Pentland 2015).

The two next most common topics were more specific discussions of the benefits V2G could provide to the grid, including both the Transmission System Operator (TSO) and the Distribution System Operator (DSO), with 31% and 15% of the interviews discussing each respectively. For TSO services, the most common subtopic was providing ancillary services, mostly frequency regulation, though one expert discussed spinning reserves. The other two subtopics were dealing with intermittency on the grid and peak shaving, often discussed in tandem. However, some experts believed that the benefits of V2G peak shaving were overstated, and the focus should be on ancillary services. For example, R163 dismissed peak shaving as insignificant as compared to ancillary services:

"Peak shaving, these are just nonsense, you don't get enough money to cover the aging of the battery. The axillary services and the frequency regulation is the one that you can actually get, you can actually make money."

Moving further down the wire, common topics of DSO services were the capacity for V2G-capable cars to delay investments in upgrading local transformers and addressing local congestion. Some viewed DSO services as a complement to V2G providing TSO services, but others viewed DSO services more dependent on the grid quality at which the EVs were located. For example, R156 believed that the V2G belonged more in rural areas, and explicitly not urban, where the grids were weak and needed help:

"[M]aybe coming from using the EVs as storage then and if the network company or some other operator would be allowed to somehow manage the batteries, there, then that would be or could be maintaining the grid, especially in the rural area, I think it has less importance in the city areas, but especially in the rural areas."

Although experts believed DSO services would be of immediate value, some were skeptical that the market was structured correctly in order to handle V2G flexibility. For example, R99 was uncertain about the future of V2G in the DSO context:

I think that's a toughest question to answer because this necessitates this kind of market or, I'm kind of, I'm not really sure I believe that there will be the DSO market, but at least some mechanisms where the DSO can start or invoke this response and also including V2G and there also be insufficient services to do so, I think there will have to be pragmatic very easy solution for that.

Moving onto the next topic, the economic benefits of V2G were discussed substantially less frequently than for EVs. Whereas 58 interviews discussed the economic benefits of EVs, only 18 discussed the economic savings as a central benefit of V2G, comprising only 8% of the interviews. Of those 18, the vast majority discussed the economic savings in terms of individual consumers (14), whereas only 3 discussed the potential savings of V2G to the grid, similarly mirroring the narrative frame for economic savings of EVs. The subset of experts that were cognizant of actual estimates of individual revenues from V2G framed these benefits as substantial and with obvious benefits. For example, as R151 puts it, earning around €1,400/year makes V2G "obvious":

"[W]e are still what we said at the beginning that we expect the revenue per car to be about ten thousand Danish kroners per car, it seems we are very much on our way to those kinds of figures. So, you know, it's an obvious business case there."

In addition, R98 imagined that the revenue potential of V2G would incentivize individuals to participate:

"The potential is gigantic…If you see your neighbor is earning 100 euros a month by being part of a scheme, you would feel stupid if you don't do it yourself."

For some experts, the economic benefits of V2G was an indisputable benefit, particularly for individuals. Practically all the estimates of V2G revenues across experts were equal, circling around 900 Danish kroner or €120 per month, seemingly based on the revenue potential from the pilot project in Denmark. Nonetheless, the vast majority of experts did not discuss precise (or any) revenues, and may have not been cognizant of the full extent of the revenue potential of V2G.

Beyond economic savings, some experts viewed V2G as providing non-economic services as well, namely emergency backup power. Many of the experts who mentioned the idea of emergency backup likewise discussed this in context of Nissan's efforts in Japan, as R233 notes:

"I see why they are doing it in Japan, in countries where they are struggling the earthquake, you need the grid or the power. And I know that they are talking about the future, and that they would be a way of have vehicle-to-grid solution."

In many cases, the experts noted emergency backup as a theoretical benefit that was better suited for countries like Japan, which faced more natural disaster threats. However, other experts still viewed emergency backup as providing value within the Nordics. R163 notes that V2G can provide essential and potentially lifesaving services in Finland if the electricity system experiences a blackout due to winter conditions:

"If you gives you additional value or market but, I think that's something which is really needed for in some parts of Finland … So it means that you have an elderly house, you may have zero backup, you may have your water purification system for the community, you have zero backup if the company who is taking care of that, has not been thoughtful."

Likewise, R179 also added:

"Another alternative is that of course when you have your own house or apartment you use that car electricity to supply that household or the limited regions because then you can in a way use that car for the critical loads which you really need that lights, and maybe the fridge and that kind of things. Which doesn't require that much electricity."

While emergency backup power may play an important role in safety, other services would provide substantially more monetary value to the EV owners (Sovacool, Axsen, and Kempton 2017; Kempton and Tomić 2005). Thus it is noteworthy that emergency backup was discussed to such an extent by the experts, and could imply that either experts were undervaluing other services or that emergency backup power should not be underestimated.

Beyond the above benefits, the remaining benefits were much less frequently discussed – more than two thirds of the categorized benefits were brought up in less than 4% of the interviews. These benefits reflect the uncertainty of the future V2G could provide. For example, 3% believed V2G could provide a number of undefined services in the future, given the capacity V2G could have available in the future, as well as changing electricity markets. For other benefits, such as micro grids, discussed by 6 experts, the potential of V2G depended on the uncertainty of a changing electricity grid– one which may become more decentralized and more reliant on storage.

Similarly, though it was not widely discussed, some experts discussed creative benefits of V2G in the context of future uses of vehicle-to-X (V2X). For example, R86 suggested that V2G should be used for a much wider variety of applications, focusing more on personal uses:

"Nissan is the only one who says you can use the battery and the warranty is there without compromise, so I think easily, their next step could be doing this and I think a lot of people would have fun about that, you can make a party at the beach, with light and everything, with this car, it can be a very powerful feature that you can use for anything, also vehicle-telescope, or whatever, just imagine what you can use it for."

While much of the V2G topics were less innovative compared to the benefits of EVs, R86 surely brought some novelty to the benefits by discussing vehicle-to-telescope. Other experts added that V2G could be utilized for other unique uses, such as music festivals, electric barbecues, road construction workers, gardeners, and charging phones, as well as more traditional V2X uses, such as vehicle-to-building (V2B) or vehicle-to-vehicle (V2V). The powerful versatility of V2X is a unique individual benefit, but focuses less on the economic benefits that V2G could provide TSO or DSO grids that the literature tends to focus on. So while V2G is primarily driven by grid considerations, insights like these show alternative business cases and benefits for other sectors.

The experts provided a wide variety of benefits that go beyond the usual economic and renewable integration benefits discussed in the literature. On the other hand, many of the complex V2G benefits, like various TSO and DSO services, may need to be better communicated even among experts, and will likely pose challenges to non-experts. For example, we found that outside of a select few electricity grid experts, the other experts were generally incognizant of the attractive economic benefits of V2G participating ancillary.

Considering that this is arguably the highest magnitude benefit, particularly for consumers (Sovacool et al., 2018; Kempton and Tomic 2005), it is important for these types of experts, particularly transport policymakers and researchers, to better understand the full benefits of V2G beyond renewable integration. Thus communication of the benefits V2G could provide not only needs to be improved, but also expanded to other various benefits described in Figure 2. We propose that future research should be undertaken to explore how this communication can be implemented, whether it be through increased academic focus within the transport field on V2G, bridging this apparent gap between transport and electricity, or alternatively, more outreach from electricity grid experts to the transport sector.

4. Conclusion and Implications

In both the cases of EVs and V2G, the benefits expressed by the experts went extensively beyond the central benefits presented in the literature. While our sample of experts acknowledged the central EV benefits around economics and emissions, they also discussed a wide variety of creative benefits. V2G benefits likewise captured the common themes of the literature like renewable energy integration and various grid services, but also submitted interesting benefits of lesser economic focus. We therefore propose that future research in personal mobility policy and development should weigh the full assortment of benefits of EVs and V2G and be open to novel and creative use of both technologies.

For example, looking forward, noise reduction may provide an important benefit not only on an individual level for the vehicle driver or passengers, but also for non-users such as cyclist and pedestrian and ultimately for urban planning and transportation; which certainly merits consideration when weighing the benefits and costs of electrifying mobility. On the other hand, benefits like noise reduction and better performance of EVs as well as V2X and emergency backup may seem like private individual benefits. However, firstly, the individual focus does not warrant exclusion of these benefits in transport policy analysis (as the literature also often investigates private economic savings) and still may improve societal welfare. Secondly these benefits impact those who drive as parts of fleet, such as electric buses, and reduction of noise and better handling may improve the safety and performance of public transportation, as drivers will have less headaches from the noise and better responsiveness during acceleration and stopping. Moreover, these benefits also impact non-users, like bicyclists and pedestrians or nearby habitants, reducing noise and increasing safety. Therefore, these secondary advantages of the electrification of mobility, while difficult to quantify, should not be overlooked when researching and creating transport and other related policy.

There was more plurality on the benefits associated with V2G, which is to some extent related to the newness of the technology and concept. This was seen in the association of V2G primarily with residential solar PV and vehicle-to-home advantages, rather than the literature-focused grid services. As pilot projects are more frequently implemented, the knowledge of V2G around its grid services potential and economic gains should and probably will be better considered amongst experts and users. But at the same time, the literature should not continue to ignore valuable non-economic benefits of V2G like emergency power backup and V2X. Moving forward, promoting the benefits of V2G and EVs may also address the social barriers they face (Sovacool and Hirsh 2009). For example, increasing the versatility that V2G can offer individual consumers may decrease resistance to using their EV for other services that may improve grid reliability and offer other wider-scale social benefits.

Clearly, the full assortment of benefits should be considered when considering EVs and V2G in transportation and economic policy analyses. Including various other benefits, like noise reduction and V2X, these may alter the analyses above such that it "tips" the scales and changes the results, especially when considering the myriad of costs and barriers that these technologies face. At the same time, the authors admit many of these benefits may not warrant inclusion, or may be difficult to include in future analyses. Thus, we also call for future research to validate the magnitude of the benefits suggested by the experts for both EVs and V2G, as well as monetize as many as possible to allow for easy integration into cost-benefit analyses.

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A. Appendix I – Overview of Semi-Structured Research Interviews

Classifications	Interviews (n=227)	Respondents (n=257)	% of Respondents
Country			
Iceland (Sept-Oct 2016)	29	36	14.0%
Sweden (Nov-Dec 2016)	42	44	17.1%
Denmark (Jan-Mar 2017)	45	53	20.6%
Finland (Mar 2017)	50	57	22.2%
Norway (Apr-May 2017)	61	67	26.1%
Gender			
Male	160	207	80,5%
Female	40	50	19.5%
Group	27		
Focus			
Transport or Logistics	73	81	31.5%
Energy or Electricity System	63	75	29.2%
Funding or Investment	10	12	4.7%
Environment or Climate Change	12	16	6.2%
Fuel Consumption and Technology	22	23	8.9%
Other	13	14	5.4%
EVs and Charging Technology	34	36	14.0%
Sector			
Commercial	68	70	27.2%
Public	37	46	17.9%
Semi-Public	40	51	19.8%
Research	37	39	15.2%
Non-Profit and Media	12	13	5.1%
Lobby	23	25	9.7%
Consultancy	10	10	3.9%

Source: Authors. Focus represents the primary focus area of the organization or person in question, sector represents the sector the company was working in (semi-public referring to commercial companies owned by public authorities, like DSOs).